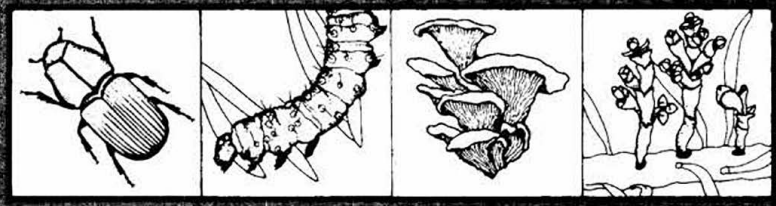
Forest Pest Management



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# FUNGI CARRIED BY ADULT FUNGUS GNATS (DIPTERA: SCIARIDAE) IN IDAHO GREENHOUSES

by

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## ABSTRACT

Eight species of fungi were isolated from external portions of adult fungus gnats (*Bradysia* sp.; Diptera: Sciaridae) adults within greenhouses at the USDA Forest Service Nursery in Coeur d'Alene, Idaho and the University of Idaho Research Nursery, Moscow. Fungus gnats were either collected from open water containers or standard yellow, sticky traps. The most common potentially pathogenic fungus isolated from adult gnats was *Botrytis cinerea*, an important foliar pathogen of several species of conifer seedlings. Three species of *Phoma*, another group of potential pathogens, were also isolated. The most common species was *P. eupyrena*, which is associated with several conifer seedling diseases. *Fusarium*, an important root pathogen of conifer seedlings, was represented by two species: *F. proliferatum* and *F. sambucinum*. All isolated fungi were carried externally on adult gnats. Characteristics and impact of fungus gnat infestations in greenhouses and control procedures are discussed.

## INTRODUCTION

Growers of container forest tree seedlings have often noticed high levels of fungus gnats (*Bradysia* spp.; Diptera:Sciaridae) associated with their greenhouse crops. Gnat larvae consume fungi and may cause crop damage by feeding directly on roots (Dennis 1978; Hamlen and Wettstein 1978), whereas adults may disseminate fungal spores which might infect plants (Gardiner and others 1990, Kalb and Millar 1986).

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Adult fungus gnats are small, dark, mosquito-like insects that do not damage plants (McHugh 1991). Their larvae are small and maggot-like, with white bodies and distinct black heads. The larvae feed on organic matter in growing media, including decaying plant debris, as well as seedling roots (Shrimpton 1991). Two species of fungus gnats are usually recognized in association with seedling crops: *Bradysia impatiens* and *B. caprophila* (Gardiner and others 1990; McHugh 1991). Many growers believe these insects may significantly contribute to decline of seedling growth and performance during greenhouse production. Gnat populations tend to intensify in portions of containers with moss or liverwort buildup at the tops of cells (McHugh 1991).

Growers may confuse fungus gnats with other flying insects occurring in greenhouses, such as shore flies (*Scatella* spp.)(Baker 1972). These latter insects generally have heavier bodies and are stronger fliers (McHugh 1991). Adult shore flies have unnoticeable antennae and dark wings with clear spots (King 1990). Adult fungus gnats appear more mosquito-like, whereas shore flies look more like common flies. Shore fly larvae can be differentiated by their yellow to brown color and lack of a distinctive head (King 1990, McHugh 1991). Shore fly larvae and adults feed primarily on algae growing on the surface of growing media, walls, floors, benches, and containers. Unlike fungus gnats, shore flies rarely damage plant material, even though they may contribute to the spread of pathogenic fungi within greenhouses (McHugh 1991).

Both fungus gnats and shore flies thrive in high moisture environments, particularly those common within greenhouses (Baker 1972; McHugh 1991). Level of plant damage caused by fungus gnats can vary; their presence is usually more of a nuisance than a production problem (Robb 1991). Seedling damage may include stunting and wilting, premature foliage loss, and chlorosis (King 1990), symptoms similar to those caused by root pathogenic fungi (James and others 1991).

Fungus gnat adults lay their eggs within growing media; after 5-6 days the eggs hatch into larvae which remain within growing media feeding on seedling roots, fungi and organic matter for about 10-14 days. They are usually confined to the top portion of plugs where they may cause damage by feeding on roots and stripping root hairs (King 1990). In severe infestations, larvae can be found tunneling through succulent stems at or below the ground line (King 1990). Larvae can also feed on foliage, especially near the ground line, and may create wounds, allowing infection by pathogenic fungi (King 1990). Pupae also form within the media and adults emerge from pupae after a few days (McHugh 1991). The entire life cycle is temperature dependent, but usually takes from 2-4 weeks, although cycles may be quicker if gnats feed exclusively on fungi (Kennedy 1974). Therefore, several insect cycles are possible during greenhouse seedling production.

Little is known about the role of fungus gnats in the epidemiology of plant pathogenic fungi. One study (Gardiner and others 1990) evaluated the interrelationships of gnats with *Pythium* root disease on different greenhouse crops. They found that during *Pythium* outbreaks, fungus gnat populations were correspondingly very high. Examination of gnat larvae indicated all forms of *Pythium* were ingested: mycelium, oospores and zoospore cysts. Digestive tracts of larvae were often packed with *Pythium* oospores, which readily germinate after being excreted. Apparently, fungus gnats were important in spreading *Pythium* root disease among different types of host plants within greenhouses (Gardiner and others 1990). Another study (Kalb and Millar 1986) demonstrated vectoring of *Verticillium albo-atrum*, an important root pathogen of alfalfa, by adult fungus gnats (*B. impatiens*). Investigators in another study found that fungus gnat larval feeding could predispose alfalfa and red clover seedlings to wilt caused by *Fusarium oxysporum* f. sp. *medicaginis* (Leath and Newton 1969). Similar investigations with greenhouse pathogens of forest seedlings have not been done.

Because of their common association with fungi and prevalence of fungi as potential causes of disease in greenhouse seedlings (James 1984b), an investigation was conducted to identify fungi commonly carried by adult fungus gnats within greenhouses. Two north Idaho nurseries, the USDA Forest Service Nursery in Coeur d'Alene and the University of Idaho Research Nursery in Moscow, were sampled in this evaluation.

## METHODS

Fungus gnats were trapped several times throughout the greenhouse production phase at both nurseries. Gnats were trapped either in open containers filled with water (University of Idaho Research Nursery) or on standard yellow, sticky cards (USDA Forest Service Coeur d'Alene Nursery) (figure 1). Periodically, traps were collected and entire fungus gnat bodies, when possible, were aseptically transferred to agar media in the laboratory. Standard potato dextrose agar and an agar medium selective for *Fusarium* spp. and closely related organisms (Komada 1975) were routinely used. This latter medium is often used to isolate root pathogenic fungi from conifer seedlings. We were especially interested in determining if and to what extent fungus gnats were carrying species of *Fusarium* within greenhouses because these organisms are common pathogens of container-grown conifer seedlings (James and others 1991). Selected fungi emerging from trapped fungus gnats were maintained in pure culture for identification purposes. Whenever possible, single-spore isolates were derived. Several taxonomic compilations were used for fungal identification (Barnett and Hunter 1972, Domsch and others 1980, Dorenbosch 1970, Nelson and others 1983).

Figure 1--Adult fungus gnat (*Bradysia* sp.) on a yellow, sticky trap within a conifer greenhouse at the USDA Forest Service Nursery, Coeur d'Alene, Idaho.

## RESULTS AND DISCUSSION

Eight identified species of fungi were isolated from external portions of fungus gnat bodies trapped at the two nurseries (table 1). The most commonly isolated species were *Botrytis cinerea* Pers ex Nocca. & Balb. and *Aureobasidium pullulans* (de Bary) Arnard. The fungal genus most often encountered was *Phoma*, with three isolated species: *P. eupyrena* Sacc., *P. glomerata* (Corda)Wollenw. & Hochapfel, and *P. herbarum* Westend. Two species of *Fusarium* were infrequently isolated: *F. proliferatum* (Matsushima) Nirenberg and *F. sambucinum* Fuckel. The other fungal species isolated was *Oidiodendron griseum* Robak. Unidentified, nonsporulating fungi accounted for about 8 percent of isolations. In several cases, more than one fungal species was isolated from a particular adult gnat.

Table 1--Fungi isolated from external portions of fungus gnats trapped at the USDA Forest Service Nursery in Coeur d'Alene, Idaho and the University of Idaho Research Nursery in Moscow.

| Fungus Species | Percent of Isolations[1] |
|---|---|
| *Botrytis cinerea* | 25.0 |
| *Aureobasidium pullulans* | 25.0 |
| *Phoma eupyrena* | 16.7 |
| *Phoma glomerata* | 8.3 |
| Unidentified (non-sporulating) | 8.3 |
| *Phoma herbarum* | 4.2 |
| *Fusarium proliferatum* | 4.2 |
| *Fusarium sambucinum* | 4.2 |
| *Oidiodendron griseum* | 4.2 |

[1] Based on relative frequency each appropriate fungus was isolated, e.g., 25 percent of all fungi emerging from adult gnats were identified as *B. cinera*.

Previous reports (King 1990, McHugh 1991) have implicated fungus gnats in disseminating spores of plant pathogenic fungi in the genera *Botrytis*, *Fusarium* and *Phoma*. Potentially pathogenic fungi implicated by others but not found in our evaluation include *Verticillium* and *Pythium* spp. (Gardiner and others 1990, Kalb and Millar 1986). *Botrytis cinerea* is an extremely important pathogen of greenhouse-grown conifer seedlings (James 1984a) and especially causes problems late in the growth cycle when seedling canopies are dense. This fungus causes disease primarily on the above-ground portion of seedlings (James 1984a), but can also reside in roots, especially those just below the ground surface (James unpublished). Apparently, fungus gnat larvae may collect *Botrytis* spores when tunneling into the base of seedlings or feeding on roots near the growing medium surface (McHugh 1991). Since *Botrytis* spores are commonly produced on necrotic foliage near the base of seedlings (James 1984a), it is also likely that adult gnats become contaminated as they emerge from growing media and move through seedling crops. The relatively high rate of adult fungus gnat contamination with *Botrytis* indicates these insects may be important in translocating this pathogen within greenhouses.

*Aureobasidium pullulans* is a ubiquitous saprophytic fungus occurring on many different substrates including soil, growing media, and the above-ground surface of plants (Cooke 1961, Hermanides-Nijhof 1977). Some strains of the fungus are especially well adapted to peat habitats (Christensen and Whittingham 1965, Latter and others 1967). Surveys indicate that *A. pullulans* is usually located on the surface layers of soil (Cooke 1970, Kendrick 1963, McLennan and Ducker 1954). This fungus may exhibit a dimorphic yeast-type phase (Domsch and others 1980); it is a common phylloplane inhabitant and its spores may contaminate any insect encountering infected foliage (Domsch and others 1980).

Although *Phoma* spp. may be important pathogens of conifer seedlings under certain conditions (James and Hamm 1985), they are more commonly saprophytic (Domsch and others 1980, Dorenbosch 1970). They often reside in soil or within growing media, but can also colonize conifer foliage, especially just above the groundline (James and Hamm 1985). These fungi are similar to *Botrytis* because they may grow saprophytically on necrotic foliage near the base of seedlings. It is likely that adult fungus gnats became contaminated with *Phoma* spores when moving through infected seedlings. Of the three species of *Phoma* we isolated, the most important, from the standpoint of causing seedling diseases, was *P. eupyrena.* This fungus has been implicated in important dieback diseases and mortality of young seedlings, especially those grown in bareroot nurseries (James 1983, Kliejunas and others 1983). This species produces common catenulate chlamydospores (figure 2) which remain viable in soil or container growing media for extended periods (James and Hamm 1985). Chlamydospores also form on necrotic seedling foliage and may be the spore stage being carried by adult fungus gnats. The other isolated *Phoma* species are usually less of a problem on conifer seedlings (James and Hamm 1985). Occasionally, *P. glomerata* may be pathogenic to conifers (Boerema and others 1971, James and Hamm 1985). It produces very characteristic dictyochlamydospores (figure 3) that readily form within soil or on other substrate colonized by the fungus. These "resting spores" allow the fungus to remain viable during inactive periods.

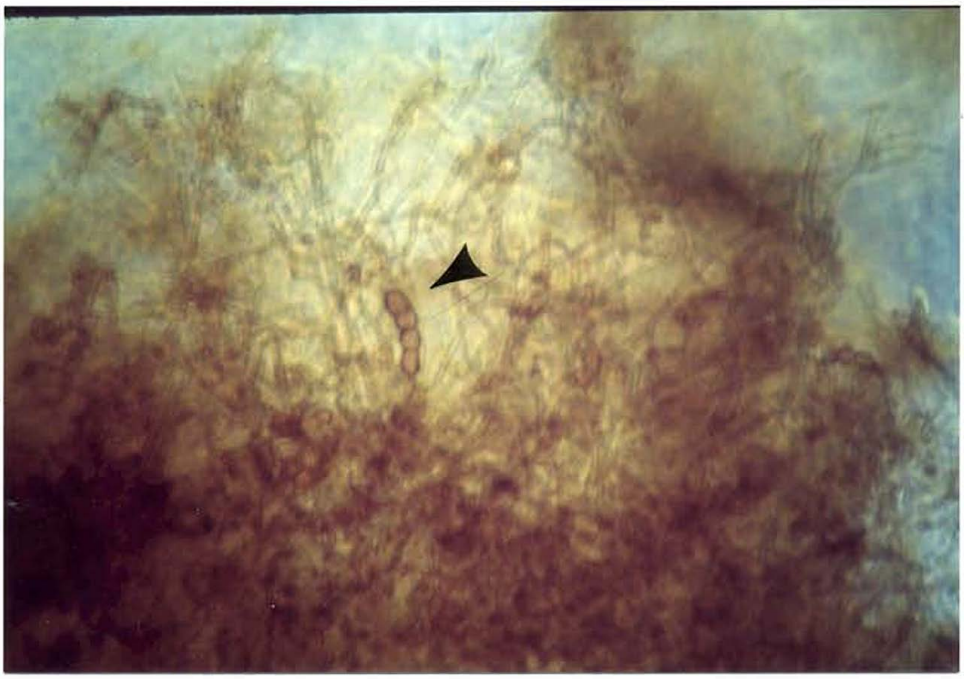

Figure 2--Catenulate chlamydospores (arrow) of *Phoma eupyrena* contaminating an adult fungus gnat (*Bradysia* sp.) from the University of Idaho Research Nursery, Moscow.

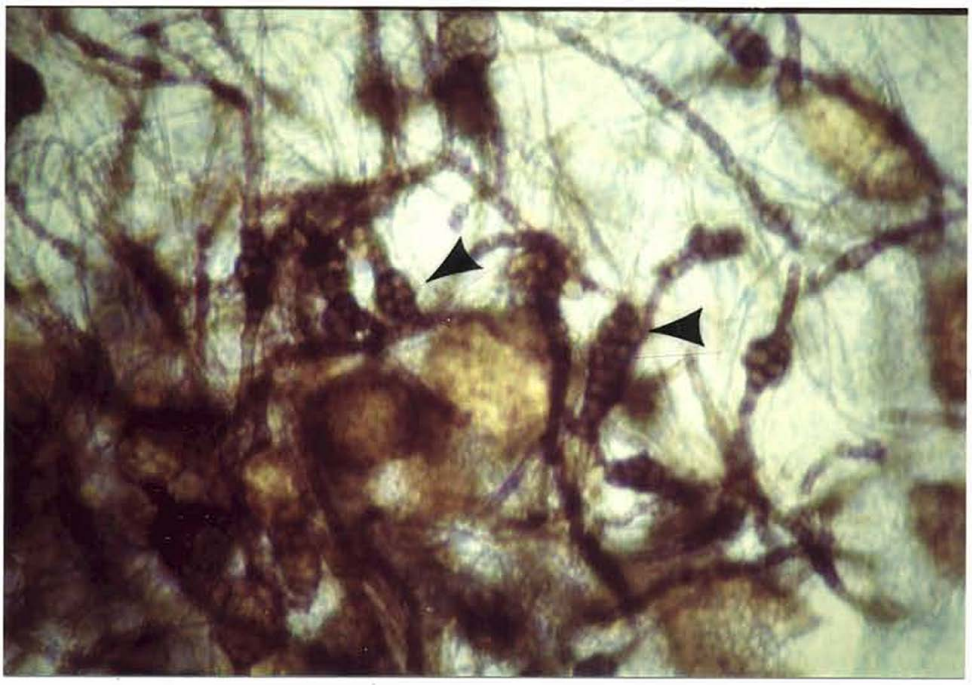

Figure 3--Dictyochlamydospores (arrows) of *Phoma glomerata* contaminating an adult fungus gnat collected from the USDA Forest Service Nursery, Coeur d'Alene, Idaho.

One objective of this evaluation was to determine if fungus gnats are important vectors of *Fusarium* spp., which cause serious diseases in container-grown conifer seedlings. Previous investigations indicated that *Fusarium* spp. cause damping-off diseases on very young seedlings, probably as a result of seed contamination (James 1986, James and others 1987). However, *Fusarium* diseases may occur throughout the growth cycle and are especially important on larger seedlings (James and others 1987, 1991). *Fusarium proliferatum* is much more common on roots as seedlings become older. This species is not a common resident of conifer seed, nor does it routinely cause damping-off. However, it is detected at increasing frequency during the crop cycle (James and others, unpublished). When seedlings are lifted from containers, their roots may often be extensively colonized with *Fusarium*, particularly *F. proliferatum*. This may occur despite lack of disease symptoms either above or below ground. However, when disease symptoms are found, this same fungus is readily isolated from roots of affected seedlings. Likewise, *F. proliferatum* can be extremely aggressive in killing young Douglas-fir seedlings in controlled pathogenicity tests; most isolates studied so far are similar in their high level of virulence (James and others, unpublished). Therefore, from the standpoint of improving disease control in container nurseries, we are interested in understanding *Fusarium* epidemiology in general and that of *F. proliferatum* in particular. The current evaluation indicated that *F. proliferatum* was only infrequently isolated from bodies of adult fungus gnats. The other *Fusarium* spp. isolated from adult gnats was *F. sambucinum*; its relative importance in conifer seedling diseases is generally unknown, although it may be isolated from seed and roots of both healthy and diseased seedlings (James and others 1989).

The other fungus isolated from adult fungus gnats was *Oidiodendron griseum*. This fungus occurs in a variety of habitats, but most commonly in wet forest soil (Christensen and others 1962; Singh 1976) and peat bogs (Barron 1962, Dooley and Dickenson 1971). It is likely that *O. griseum* was a saprophytic inhabitant of the peat/vermiculite growing media used in conifer greenhouses, existing in dead organic matter (Domsch and others 1980).

## FUNGUS GNAT CONTROL

Several approaches for reducing fungus gnat populations in greenhouses are available. yellow, sticky cards can be used to monitor fungus gnat populations because adults are attracted to the yellow color (Parrella 1987). When little plant damage occurs from fungus gnats, direct control measures are unnecessary. Reducing the proportion of organic matter in seedling growing media may help limit buildup of gnat populations (McHugh 1991). Since excessive moisture is required for maintenance of high gnat populations, wet areas should be eliminated and moisture drainage from growing media improved when possible (King 1990, Shrimpton 1991). It is especially important to avoid overwatering and provide adequate ventilation to ensure that greenhouses dry out between irrigations (McHugh 1991; Robb 1991). Overall sanitation, such as removal of greenhouse weeds and sterilizing surfaces of benches, floors, and walls between seedling crops will help control gnat populations (King 1990, Robb 1991). If necessary, shore flies can best be controlled by reducing algal growth by minimizing excessive moisture and by incorporating chemicals such as Agribrome® into irrigation water (King 1990, McHugh 1991). Application of hydrated lime or copper sulfate to greenhouse floors can also reduce algal growth (McHugh 1991).

Adult fungus gnats may be controlled using yellow, sticky ribbons. Past experience (Shrimpton 1986) indicated that populations can be controlled successfully in greenhouses by placing these ribbons at a density of one per ten square feet.

Chemical pesticides should usually be applied only in response to either very high insect levels or noticeable seedling damage (McHugh 1991). Pesticide applications on a routine basis during the growth cycle are unnecessary and not recommended (Hussey and others 1969). Several pesticides that have given good control of adult fungus gnats include diazinon, bendiocarb, acephate, and oxamyl (King 1990).

The larval stage is easy to control (King 1990) and biological control formulations are either currently available or being developed for use against greenhouse populations of fungus gnat larvae. Parasitic nematodes (*Steinernema carpocapsae*) are available under various trade names (i.e., Exhibit®) from several companies (King 1990; McHugh 1991). Nematodes are applied as an aqueous drench directly onto the surface of growing media; nematodes feed on gnat larvae just below the groundline. Another biocontrol agent is a brown mite (*Hypoaspis miles*) that feeds on gnat eggs and larvae (McHugh 1991). Mites are produced as a mixture of eggs, nymphs, and adults, and are sold mixed with a combination of vermiculite and peat which can be used as the container growing medium. Mite preparations can also be used to treat greenhouse floors and benches. A formulation of *Bacillus thuringiensis* called Gnatrol® has also proven effective in greenhouses (King 1990). In general, parasitic nematodes give longer control because they are active for up to 6 weeks, wherease *B. thuringiensis* treatments only last a few days. Therefore, several applications of *B. thuringiensis* are necessary to control successive gnat generations.

Another approach to reducing populations of gnats in greenhouses is application of insect growth regulators such as Dimilin® (King 1990). This material is currently being developed as an alternative to more commonly used chemical pesticides.

## CONCLUSIONS

In conclusion, our evaluation indicated that fungus gnat adults may be important carriers of potentially pathogenic fungi in conifer seedling greenhouses. Although we only evaluated organisms carried passively on bodies of adults, it is possible that some of these or other fungi might be disseminated shorter distances by larvae. Specific fungal species may also be preferentially fed on by gnats. Correlations between high fungus gnat populations and extensive damage by fungal diseases in conifer greenhouses have not been documented. Nevertheless, many growers feel it is important to limit gnat populations to ensure production of healthy seedling crops.

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